

# Noncontact Diamond Tool Metrology

In the fabrication of high-energy-density physics target components, we often need to use radically configured diamond tools with small nose radii and high clearance angles (making a “sharper” tool) that are extremely fragile. The tool geometry is driven by the need to access features with very small spatial wavelengths (high-frequency sine waves) or small radii, such as small hemispherical shapes. The LLNL standard approach to tool setting is an air-bearing LVDT, but with these fragile tools, there is risk using a contact method. Identifying noncontact diamond tool measurement technology would allow LLNL to minimize the risk of damage.



Figure 1. Typical diamond tool geometry for HEDP target fabrication, 1/4-in. shank.



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## Project Goals

The goal of this project is to evaluate the current state of the art for measuring diamond tool position, non-roundness, and nominal radius, using noncontact methods.

## Relevance to LLNL Mission

Commercial diamond turning machines (DTMs) come equipped with a microscope/digital-camera-type tool set station that is accurate to only a few microns. A modest improvement in the commercial noncontact tool setting system will allow higher efficiency in the fabrication of targets. If the resulting performance is better than that of air-bearing LVDTs, both in higher accuracy and improved spatial resolution, the system could be applicable to many of the precision machining and inspection applications at LLNL.

## FY2004 Accomplishments and Results

Figure 1 shows a typical diamond tool geometry. To determine tool metrology requirements, three distinct classes of machines are considered: commercial machines from Precitech and Nanotechnology Systems with approximately 100-nm accuracy and 10-nm resolution; state-of-the-art machines such as LLNL's LODTM with 25-nm accuracy and 2.5-nm resolution; and next generation machines with 10-nm accuracy and 1-nm resolution. Using these machine specifications, resolutions and accuracies

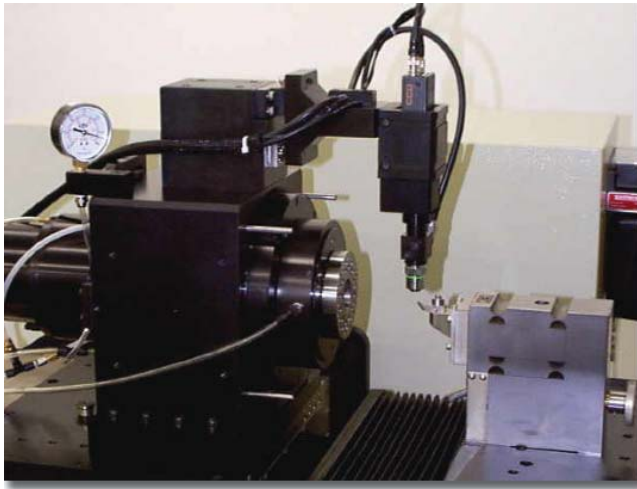


Figure 2. Commercial optical diamond toolset station from Moore Nanotechnology Systems.

for tool parameters are determined. Profile or non-roundness requires the highest resolution because of the desire to capture high spatial frequency edge deviations. Size and position can be determined using lower resolution systems by averaging over the entire edge and curve fitting. Optical microscopy could be used for size and position, but would be completely inadequate for profile measurement.

Figure 2 shows a sample commercial optical diamond toolset station. Target fabrication uses DTMs with two different commercial toolset stations. Both of these stations suffer from the same shortcomings for precision manufacturing. These systems rely on the operator's selecting points on the tool edge from a display of the tool image. This is heavily dependent on not only the operator's qualitative judgment, but also the quality of the display. These cameras are analog output cameras, which can result in lower picture quality, and their optical subsystems are relatively low, fixed magnification. They are for much larger tools than are currently used in target fabrication. These

systems could be improved with higher resolution cameras and higher magnification optical systems. Edge detection software could also enhance the toolset station size and position capability to the sub-micrometer level.

For profile measurement, an instrument with nanometer level resolution is required. One commercial instrument has been identified which claims to allow optical measurement of tool profile to nanometer level. The NanoInSPEC Edge Scanner can be purchased with 1-nm lateral position resolution. Although this system is expensive, it could be used to profile tools off the machine, while cheaper toolset stations are then used to locate the tool within the machine work volume.

For current and next generation machine tools, noncontact diamond tool metrology will be possible. This project determined that tool profiling requires nanometer resolution capability, while size and position can be obtained through lower resolution techniques using averaging and curve fitting.

### Related References

1. Soares, S., "Nanometer Edge and Surface Imaging Using Optical Scatter" *Precision Engineering*, **27**, pp. 99-102, 2003.
2. Morantz, P., "A Nanometric Precision Noncontact Toolsetting System," *Proceedings of the 7th ASPE Conference*, pp. 18-21, 1992.
3. Zhou, W., and C. Lilong, "Method for Edge Detection Based on Phase Jump in a Differential Interferometer," *Applied Optics*, **38** (1), pp. 152-159, 1999.

### FY2005 Proposed Work

The next step should be to upgrade current DTM toolset stations and verify that they meet size and position measurement requirements. A commercial system is available which may meet our requirements for noncontact profile measurement. This instrument should be evaluated and, if accurate, purchased for diamond tool profiling.